LA-UR-83-929

LA-UR--83-929

Conf-830532--1

DE83 009897

TITLE: FROM AFRICA TO THE STARS

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SUBMITTED TO 6th Princeton Conference on Space Manufacturing, Princeton, NJ, May 9-13, 1983.

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From Africa to the Stars

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We Homo sapiens are by nature wanderers. Our very evolution has been shaped by the restlessness and technological adaptability of our ancestors from the time those most adventuresome of apes left the shelter of the tropical forest to roam the grasslands of East Africa. Now, we, the sole surviving species of hominidae, stand on the threshold of space, ready to expand into the Galaxy. If we do succeed in colonizing space, humanity will never be the same again, for we will have opened the door for our accelerated evolution. The question of whether or not we shall expand into space can, therefore, be rephrased. Freeman Dyson (1979: 234) aptly puts the question: "Shall we be one species or a million?"

To develop the thesis that our evolutionary future, like our past, is tied to our penchant for exploration and migration, we proposed to examine the main stages of human exploration and migration, and the evolutionary implications of each, starting from the time our distant ancestors first stood upright and continuing into the coming era of space expansion:

(1) From Tropical Forest to Savanna

(2) From East Africa to Eurasia, the Americas and Australia

(3) From Land to Sea

(4) From Earth to Space.

(1) FROM TROPICAL FOREST TO SAVANNA

Where and when does the story of human evolution begin? Most paleoanthropologists would place the birthplace of hominidae---that is, all erect-walking primates---on the continent of Africa, specifically in East Africa. As Darwin (1871: 177) first pointed out, it is in Africa that our closest relatives, the Chimpanzee and Gorilla, live, and, since Darwin's time, it is in East Africa that the oldest hominid fossils have been found. These date back to some 3-4 million years (Johanson and White 1979; Scientific American 1982; Wilford 1982), but are not thought to represent the very oldest of hominids. Although some have tried to push the beginnings of hominidae back to some 10-15 million years ago on the arguable basis of a few fragmentary bones (Pilbeam 1975), most paleoanthropologists accept a more recent date (Lowenstein 1982). New techniques of comparing chromosomes, serum proteins and hemoglobins between man and apes, and calculating the immunological distance between them, indicate that the separation of the first hominids, our first erect-walking ancestors, from our ape relatives took place some 5.5 million years ago (Sarich and Wilson 1967; Goomand and Tashian 1976; Yunis and Prakash 1982).

The first "giant leap for mankind," to borrow Neil Armstrong's phrase, was the descent from the sheltering trees of the tropical forest to the open grassland-woodland environment of the savanna made by those as yet unknown ancestors who, in so doing, set the train of human evolution in motion. These were literally the first steps toward Mankind for they were made on two legs instead of four. This postural revolution left the forelimbs free to make and manipulate tools, to carry babies, food and other goods, and to perform a myriad of tasks which were to make this animal, and its descendants, so unique.

But this move into the grasslands was hardly, as some popular writers have imagined (Ardrey 1974), an invasion of bloodthirsty hunters into the savanna. The earliest Australopithecines known from the fossil record were small, generalized creatures, wholly lacking the ripping teeth or other natural adaptations of successful predators. For example, the oldest nearly complete skeleton known is that of the famous Lucy of Ethiopia who stood a bare three and a half feet tall, weighed a scant 60 pounds or so, and had a set of almost human-like teeth (Johanson and Edey 1981: 274). Without a highly sophisticated hunting technology such a modest creature could hardly have topped the savanna food chain; indeed, the archaeological record indicates that such a technology did not develop until several millions of years after the move from the forest into the savanna.

How, then, did these tiny hominids survive and prosper? The Australopithecines became the premier food gatherers of the savanna (Tanner 198'). Their bipedal posture, with that crucial freeing of the hands, enabled them to tap a wide range of grassland resources: to gather nuts, berries, birds' eggs and grubs; to dig up succulent tubers and roots; and to catch insects, small animals and perhaps also the young of larger animals. Yet, they did not accomplish all this with their bare hands. In fact, Australopithecus was probably the first creature to have to depend for its survival upon technology, however rudimentary. Although the hard archaeological evidence has not survived, the most crucial tools were probably made of wood, fiber or skin: digging sticks; simple containers and other rudimentary implements to aid the gathering of food. A new economy was now possible. With these simple tools, mature, able-bodied, males and females could range over the countryside in search of food. Then, instead of consuming it on the spot as their ape cousins did, they could, thanks to their erect posture and free hands, carry the food back to a base camp to share with dependent children and adults who had stayed behind. This new food gathering way of life was thus the beginning of a home-based social organization with all its implications for family formation, prolonged nurturance and training of the young and for sharing and communication.

Yet, for all its evolutionary advances, Australopithecus apparently did not expand beyond the savannas of Africa. To migrate further required, it seems, further evolution. Within the Australopithecus genus there was speciation. The first known hominid species, Australopithecus afarensis, was followed by at least two successor species that survived up until 2 to 1.5 mya: a gracile type that developed further the generalized omnivore niche pioneered by its distinguished ancestor; and a robust type which, as witness its massive jaws and molars, must have specialized on a diet of course and gritty tubers and roots. Although a few paleoanthropologists, notably those from the famous Leakey family, reject direct descent from any known Australopithecus species, most experts see further evolutionary advance in hominidae as coming from either afarensis or its similarly gracile descendant.

(2) FROM AFRICA TO EURASIA, THE AMERICAS AND AUSTRALIA

Paleoanthropologists speak of mosaic evolution, of the accelerated evolution of parts of the body while others remain relatively static. Thus, while Australopithecus made the tremendous advance to erect posture, with all the modifications of the feet, legs, and pelvis that required, over the 2-3 million years the genus is known its brain remained small, averaging around 500 cc, hardly bigger than that of its chimpanzee cousins (Campbell 1982: 148). Then, starting about 2 mya, the evolution of the brain begin to accelerate. The first evidence of this trend comes from the skull of the so-called "Handy Man" (Homo habalis) discovered at Oldavai Gorge, Tanzania by the late Louis Leakey (Leakey, Tobias and Napier 1964). Although some students would classify it as an advanced Australopithecus, most have accepted Leakey's assignment of it as the first known representative of our genus, Homo. This is both because of its significantly greater brain capacity of 650 cc, and undeniable association with worked stone tools. Although recent discoveries would seem to confirm the long-held conjecture that Australipithecus must have used rudimentary stone tools (Kalb et al 1982), by the time Homo habilis appears the distinctly human synergy between the development of increasingly sophisticated tools and the acceleration of brain development seems to be definitely underway (cf Washburn 1967).

Although skull fragments unearthed on the island of Java may indicate that Homo habilis was the first hominid to leave Africa (Tobias and Von Koenigswald 1964), the next species of Homo to evolve, Homo erectus, is generally credited with being the first hominid to spread in any numbers beyond Africa; its fossil remains have been found widely scattered over Eurasia. In fact, the first Homo erectus fossils were found not in Africa, but far away in what is now Indonesia ("Java Man"), China ("Peking Man") and Germany ("Heidelberg Man"). Only recently have Homo erectus fossils begun to turn up in African sites.

Homo erectus was significantly brainier than his predecessors.

Fossil skulls range in brain capacity from around 775 cc to 1225 cc, thus overlapping the low end of the Homo sapiens range (Campbell 1982: 289). This advanced hominid employed a more highly developed stone technology---inventing, apparently, the art of chipping stone on both sides to make a keener edge--- and was a successful big game hunter. This involved a critical shift in the savanna niche pioneered by his Australopithicus ancestor---from that of a food gatherer who also caught some lizards, birds and other small animals, to that of a hunter and gatherer who, in addition to harvesting wild vegetable foods, began to prey systematically on large herbivores. This shift may have had an important physiological dimension (Brace and Montagu 1977: 323). If our relative hairlessness and abundance of sweat glands, and hence our outstanding ability to dissipate heat through copious sweating, evolved at this time, Homo erectus hunters, unlike other predators which hunted in the cool of the late afternoon or evening, could operate in the heat of the day, catching prey unawares or running them to exhaustion. But, above all the shift to a hunter emphasis had a specifically cultural dimension. Hunting technology, involving both tools and organization, now came to the fore. For example, as can be reconstructed from excavated kill sites, these hunters skillfully employed guile and teamwork to drive large animals, even elephants, into bogs or other traps where they could be slaughtered with spear or club, and then butchered with finely-chipped cutting tools.

This hunting adaptation enabled small bands of Homo erectus, over many generations, to wander north out of Africa and then pursue game east and west over the warm savannas which, at the beginning of the Pleistocene some 1.5 mya, stretched the length of South Asia and into Southern Europe. Once in Europe and Asia, however, these hairless, tropically-adapted, hominids would have been subject to cold stress as the glaciers began to form and periodically advance southward. Yet, archaeological evidence indicates that Homo erectus bands roamed far to the north in treeless grasslands so rich in game but so much colder than the African savannas. Fire blackened hearths found at some of these sites and dating as far back as 700,000 years reveal that these hunters had learned to control fire---one of the single most important innovations in cultural evolution. With the ability to keep warming fires burning, and to gain further protection from rude shelters and animal skins, Homo erectus was able to penetrate far to the north, reaching at least latitude 49 degrees north during interglacial periods (Campbell 1982: 292-3).

Yet, for all his hunting skill and cultural ingenuity, during the million or so years of his existence, Homo erectus did not succeed in spreading beyond the linked continents of Africa, Asia and Europe. The move to the Americas and Australia followed further cultural development and the evolution of a new species, Home sapiens.

The details of the origin Homo sapiens are far from clear. Fossil skulls found in Western Europe that date back some 250,000 years show an unmistakable trend toward greater cranial capacity, and toward the high, vaulting shape of modern skulls---with all that implies for increased mental capacity. Yet, in Europe at least, the gap between these evolving skulls and the late appearance around 40,000 years ago of modern Homo sapiens is filled with the abundant remains of the famed Neanderthal Man whose projecting face, beatle-brows and thick-set build would seem to belie any smooth progression to modern forms. In fact, until recently many scholars classified Neanderthal as a separate species. an evolutionary dead end. However, because of better reconstructions of his skeletal remains, a realization of the fact that at 1600 cc his brain was slighter larger than the the average for modern man, and an appreciation of the possibilities for microevolution under climatic stress, many students are now inclined to classify Neanderthal as an early form, or sub-species, of Homo sapiens, one physiologically adapted to the bitterly cold conditions of the late Pleistocene (Brace 1964). Yet, even this rehabilitation of Neanderthal does not solve the mystery of exactly where and when Homo sapiens originated. Was it somewhere in Europe or Asia, or was Africa the cradle of modern man as well as his ancestral forms?

Whatever the case, for our purposes the important point is that Homo sapiens were the first to populate the hithertofore empty continents. The drastic lowering of sea levels by 80 to 100 meters during the last glaciation of the Pleistocene facilitated this movement---by exposing the continental shelves so that Siberia and Alaska were joined by a land bridge, while Indonesia became an extension of Asia reaching out almost to the shores of a greater Australia composed of the present continent, New Guinea and surrounding shelves. Yet, previous galciations had similarly lowered sea levels without any migrations taking place. The crucial ingredient was the evolution of Man's cultural capacities and techniques (Birdsell 1957: 47). Refined hunting tools and techniques, tailored skin clothing and other survival gear enabled Homo sapiens, to penetrate the Arctic; then, all that had to be done to reach America was to follow prey across Beringia (as geologists dub the broad plain that then linked Asia and North America). Similarly, once simple rafts and rudimentary techniques for living off sea and coastal resources had been developed, people could cross the narrow stretches of open water then separating Sundaland (glacially-enlarged Indonesia), and Sahuland (greater Australia).

When exactly this took place is still subject to debate. Previously, scholars thought that these movements could not possibly have taken place until as least 12,000 years ago and probably much later. Now, however, the discovery of respectably ancient human fossils in the middle of Australia, leads many archeaologists to estimate that people first crossed to Sahuland during the last glaciation some 50,000 years ago (Allen, Golson and Jones 1977). And, although the status of similarly ancient remains in North America is still subject to dispute (Bada and Finkel 1982), similarly early (and even earlier) estimates of the first crossings of Beringia are being increasingly voiced (Reeves 1981).

Whatever the exact datas, by surmounting tropical and arctic barriers, and then by spreading over the forests, mountains, plains, deserts and jungles of the three new continents, these ancient wanderers highlighted the unique ability of man to adapt culturally to new environments. Building on the biological foundation of erect posture, brain expansion and associated developments of hominid evolution, our more recent ancestors added the capacity to invent and apply technology to make human existence possible from Africa to the Americas, from the tropics to the arctic. Where other animals had to evolve biologically to move into habitats radically different from the ones for which they were specifically adapted, Homo sapiens, the hairless biped from the African savanna, could adapt culturally. Thus, by the time of the last glaciation, cultural evolution had supplemented biological evolution to make Homo sapiens a uniquely world-wide species.

(3) FROM LAND TO SEA

However, to claim that late Pleistocene Homo sapiens spread over the entire world is to ignore that fact that we live on the water planet. Seventy percent of the Earth's surface is water, and it is only in comparatively recent times, after the advent of the Agricultural Revolution, that we learned how to sail over the oceans and use them as avenues for migration and trade if not actual places to live.

Probably the first to sail far out to sea---as opposed to merely coasting along known shores or between closely-spaced islands---were the Polynesians. Their ancestors are thought to have begun their seafaring career off south China or the islands of Southeast Asia 5,000 or more years ago. Archaeologists pick up their definite trail on small islands off New Guinea where they sojourned some 3,000 years ago. From then the story is one of increasingly longer voyages into the open Pacific made to search out and colonize islands separated by hundreds and in some cases thousands of miles of blue water. By 750 A.D. they had discovered and settled virtually every island within a vast oceanic realm the size of most of the Europe and Asia combined (Finney 1977).

Of all the episodes in human expansion over this globe, the Polynesian one stands out as a haunting precursor to the coming expansion into the archipelagoes of space (Finney 1981). Just as we hope to humanize space, so did the Polynesians spread humanity far and wide through a then-alien environment, discovering and settling comparatively tiny specks of rock and coral amidst the oceanic wastes. Yet, for all the inspiration this Polynesian experience may provide, it was an historical dead end. Even if alien voyagers had not intervened, it would be difficult to imagine the continuation of Polynesian expansion, for they had run out of archipelagoes and were in effect trapped between the already-populated land masses of Asia and America.

The true discoverers of the global sea were those European navigators who, in learning how to sail between continents and eventually around the world, were the first to realize that there is but one ocean and that it could be used as a highway to connect hitherto-isolated or only tenuously linked lands and populations (Parry 1974). The global consequences of this discovery followed quickly upon those first tentative expeditions into African waters organized by Prince Henry, the pioneering transoceanic voyages of Da Gama and Columbus, and then that first circumnavigation by Magellan---all of which took place within a century. But the effect of this maritime expansion was not solely the territorial and commerical aggrandizement of a handful of European powers. Centuries hence, when the anger and guilt over colonial exploitation has faded, the true aftermath of this European Age of Exploration will be seen to have been the bringing together of the disparate branches of mankind into one world system.

Why should a few small, economically-backward states on the western fringe of the Eurasian land mass have been the ones to initiate this reunification of humanity? Contemporary historians have updated the old explanation of rapacious Western greed. They are fond of pointing out that it was the economic crises then affecting late feudal Western Europe that drove its sailors out to sea, and forced its princes and bankers to support them (Godinho 1965; Wallerstein 1974). Yet, Portugal, Spain and other European nations that turned to the sea had no corner on poverty and economic disorder; only their creative solution was unique. We side with earlier historians who pointed to the key ingredient of motivation--

-the drive to explore the seas and seek out new routes and lands---as crucial to the discovery of the sea and its consequences. Similarly, we are impressed with how the exploratory drive of the ancient Polynesians led them to expand faster and farther into the Pacific than population pressure could have pushed them.

We raise this motivational issue to refocus on the premise with which we started this analysis: that we are by nature explorers. That is, of course, true in a general sense for all vertebrates, and many invertebrates, as well as man (Baker 1980: 15). In this, mankind is not alone. To survive, animals must explore their environment to find sources of food and living space, and a successful species is one that expands its habitat through the migration of its members. In hominid evolution this basic urge to explore has been developed further, to the point where it is leading us to leave our ancestral planet.

Man is the one animal that has professionalized exploration. It is the juvenile of most animal species who do the exploring, investigating their environment before settling down on a limited geographical range from which, as adults, they hardly stir. Modern man, from the Australian Aborigine to the denizen of an industrial city, follows a similar pattern of juvenile exploration---of the waterholes and sacred places of the desert, or of the sights and experiences of touring Europe or backpacking in the Sierras---before settling down to the routine of adult life (Baker 1980: 239). Yet, some adults do not give up their exploratory bent and, in fact, make a career of it. Columbus did this through sheer entrepreneurial genius; by the late 18th century maritime exploration had matured to the point that Captain Cook could claim to be "employ'd as a discoverer" (Robertson 1971). Now we even have people who make their living by exploring the stars and planets through telescopes and robot spaceships, and a growing corps of astronauts, cosmonauts and spacionauts (Ben: never seen this word) who actually explore space in person. We are the animal that has turned a juvenile characteristic into an adult passion.

This is as much part of our genetic evolution as it is our cultural development. Man's hypertrophied exploratory urge stands out as a behavioral manifestation of his neotonous evolution. Sixty years ago the Dutch anatomist Bolk noted how in brain-to-body ratio, domed head shape, absence of snout and other linked features, adult humans resemble foetal apes, and proposed that we become brainy humans through the process of neotony. After a long eclipse, this theory has taken on new life with research on how mutations in just a few growth-regulating genes can radically alter the proportions and character of any organism. The tremendous expansion of the brain relative to the body during hominid evolution could, according to this theory, have followed from mutations in a few regulatory genes so that the brain, already large at birth, continued to grow into adulthood while somatic growth was relatively retarded. Following some observations made by the ethologist Konrad Lorenz (1971: 180), we can carry this reasoning futher. He notes how man has retained a range of juvenile behavioral traits into adulthood, most notably the penchant for investigating and exploring his environment. Unlike our ape cousins, expecially the dour gorilla, we retain our childhood curiosity into adulthood. This retardation has served the species well, for it forms the basis for our inquisitiveness into the nature of things (cf Planck 1942) as well as our incessant search for what lies over the horizon---for, in other words, science and geographical exploration. Through neotony we have become a most-inquistive, exploring ape.

(4) FROM EARTH TO SPACE

Have we stopped evolving? According to the noted paleontologist, Stephen Jay Gould, since the advent of Homo sapiens in Europe some 50,000 years ago we have not a shred of evidence for genetic improvement. He even suspects that the average Cro-Magnon, properly trained, could have handled computers with the best of us, and concludes that all we have accomplished since his day has been, for better or for worse, the result of cultural evolution (Gould 1982: 83). In this cosmically insignificant, even geologically-trivial, period of 50,000 years the Earth's population has, Gould continues, gone "from perhaps one hundred thousand people with axes to more than four billion with bombs, rocket ships, cities, television, and computers---all without substantial genetic changes."

Yet, in the writings of Gould and other like-minded paleontologists (Eldridge and Gould 1982; Stanley 1979, building on the work of Mayr 1954 and Simpson 1944), can be found a theory of evolution which tells us, if interpreted in the light of our coming dispersion into space, that we are on the threshold of quantum biological evolution. These theorists have gone beyond the gradualist tenet of the so-called Modern Synthesis of evolutionary theory by proposing that, contrary to the old adage, nature does make leaps. They maintain that major evolutionary divergence proceeds through bursts of speciation, through the comparatively rapid splitting off of separate lineages from the ancestral stock, and not by the gradual transformation of that stock. This quantum speciation occurs, they propose, in very small populations that have become geographically isolated from the ancestral stock. Where genetic change is resisted by large populations well adapted to their environment, favorable genetic mutations can easily gain a foothold in marginal geographic areas where pressure for natural selection can be intense, and then spread quickly through the small populations that have become isolated there.

They further propose that this theory of quantum evolution makes better sense out of hominid evolution than the long prevailing gradualist one. Instead of reading the fossil record as if it indicated a smooth and gradual progression of a single lineage from an ape-like ancestor, through three or four species of now extinct hominids, to modern Homo sapiens, they see evidence of a more complicated branching structure in which various fossil species spring from small popultion isolates, grow vigorously for a time only to be overtaken by other species which flourish while they wither. In this view, Homo sapiens are not the final rung of a single evolutionary ladder going back 5 million years or more, but merely the "only surving branch of a once luxuriant bush" (Gould 1979).

Conditions were at times ideal in our hominid past for such genetic experimentation. Until the advent of the Agricultural Revolution some 10,000 years ago, all hominids lived in small bands scattered thinly over the countryside. In some regions geology and climate seems to have combined to enhance the isolation of these bands, and to increase the selective pressures acting upon them, thus leading to a vigorous speciation response. Take, for example, East Africa, the posited homeland of the original hominid species and at least three subsequent ones. During the Plio-Pleiostocene era in question, East Africa was a most unstable region: the two plates underlying this rift zone were pulling apart, causing massive uplift and subsidence, and volcanic activity which broke the countryside into diverse and discrete local environments (Isaac 1976: 124-5). These topographic upheavals, perhaps exacerbated by marked fluctuations in rainfall and hence vegetation, would have stressed the small bands of hominids then unconciously experimenting with a new way of life, and would have further isolated individual groups in scattered refuges, thereby setting up conditions that would promote the rapid speciation of hominidae indicated by the fossil record (Tanner 1981: 137).

But, through our massive population growth, and the development of modern means of mass transport, we, as the surviving hominid species, are no longer broken up into small, isolated breeding populations. Furthermore, our cultural and technological ingenuity has enabled us to adapt to the diversity of the world's environments and has, thereby, greatly relaxed selective pressures. It can even be argued that since all members of a community benefit from cultural developments, the selective pressure for greater intelligence is removed. Finally, the self-consciousness so basic to our cultural nature would seem to prevent the spread of adaptive mutations that might radically alter our appearance or character. The advent of a "hopeful monster," to use the geneticist Goldschmidt's phrase (Goldschmidt 1940), is not likely to be greeted with any joy---especially by prospective mates---no matter how adaptive its monstrous features might be.

But what holds for Earth may not hold for space. We maintain that the human race is actually on the threshold of quantum biological evolution because some of us are not content to stay in the terrestrial cradle. Once we---or rather some of our descendants---spread far and wide enough, the forces for genetic change now braked on Earth will be released once more. In particular, our extra-terrestrial descendants will experience that prerequisite for rapid evolution that our ancestors once knew: isolation in small, scattered communities.

This would probably not come to pass during the first stages of space migration. We will begin to learn how to live in space by colonizing the inner Solor System---by making small corners of the Moon habitable, and by using the abundant resources of the moon and Earth-crossing asteriods to build actual space colonies at the Lagrangian points in the Earth-Moon system or other suitable locales (cf O'Neill 1977). Although these early settlements would start small, and might give the illusion of isolation, they would soon grow and their inhabitants would never be very far in travel time, much less communication time, from other communities. There would seem little chance of recreating conditions propitious for major evolutionary change. For example, David Criswell (1981: 1168) envisions swarms of hundreds of thousands of space colonies located in regions like L-4 or L-5. Each swarm could, he estimates, contain a total population of hundreds of billions of people.

However, once the technology of space travel and colonization advances to the point where the price of mounting an independent colonizing mission comes within the reach of, say, an extended family or a small group of like-minded volunteers, such tiny bands will set off the colonize the multitudinous asteriods and comets of the outer Solar System (Dyson 1979: 118-26: O'Neill 1977: 223-48). Yet, even though these might shelter small populations for generations, we doubt that they would be sufficiently isolated from one another and from major Solar System settlements to provide the ideal conditions for evolutionary divergence. What they would do, though, is provide a proving ground for developing the technology, both material and social, for colonizing truly distant and isolated chunks of matter where we are betting that the first speciation of our genus will begin.

We refer to interstellar comets, those comparatively miniscule icy bodies which, through the application of energy obtained by the fusion of cometary deuterium or by gathering starlight in huge, spindly mirrors made from cometary aluminum, could be made habitable for small and adventurous groups of pioneers. Elsewhere (Jones and Finney 1983) we have developed a scenario of colonizing first the comets of the Oort Cloud loosely bound to the Sun at a distance of hundreds or thousands of astronomical units, and then those comets wandering in interstellar space. Because of the extremely restricted energy resource, reinforced perhaps by the desire of some maverick groups to return to living in the small, face-to-face communities our pre-agricultural ancestors knew, we proposed that a typical population distribution might be co-living groups of as few as 25 people joined through marriage exchange to make up breeding communities of some 500 men, women and children. One comet could support such a breeding community. It is in these tiny isolates, particularly those at the very edge of our star system or others we have colonized, or wandering free in space, that we expect the first major evolutionary divergence to occur.

These small human bands might welcome any mutations that would adapt them better to their bleak and unearthly environment. The appearance of a "hopeful monster" who could cope better with the peculiar environments of space (zero gravity, high radiation density, exposure to vacuum) or even the as-yet-unforseen peculiarities of a simulated terrestrial environment might well be greeted with joy rather than disgust. And, if genetic engineering techniques were perfected and available to such marginal communities there might be an overwhelming temptation to artificially stimulate adaptive evolution to their environment of choice. In so doing they would probably be going against the main body of human sentiment which then, as now, would undoubtedly balk at the idea of new hominid species. Public opinion might even be backed up by attempts to restrict the flow of radical mutations and especially their artificial creation. However, those adventuresome souls living amidst the comets would probably be fairly immune to the blandishments of the human crowd from which they had fled, and be too far away and difficult to reach to be policed.

Thus from such small and marginal groups further human evolution may flow. But, however exotic the extraterrestrial circumstance might seem, the process would basically replicate that followed by those exploratory-minded founders of ancestral hominid species, or just about any species for that matter. In evolution it is typically from the adventuresome minority, not the main stock, that evolutionary advance flows (Stanley 1979: 206).

This advance will not be limited to the birth of one new species. Space is not a single environment, but a residual category for everything outside the Earth's atmosphere. There are innumerable environments out there, and perhaps even more niches to be developed for the exploitation of those environments. By spreading into space we will embark on an adaptive radiation of hominidae that will spread intelligent life as far as technology or limits placed by any competing life forms originating elsewhere will allow. This radiation of evolving, intelligent life through space will be the galactic successor to the other great episodes of adaptive radiation in the evolution of life---that which followed the wandering of a few fish onto land, or the opportunistic multiplication of mammillian genera and species to fill the vacuum left by the disappearance of the dinosaurs.

But, don't ask us what specific forms this radiation will take, what new species will look like, or whether some will preserve only their intelligent essence within voyaging computers as Jastrow (1981: 162-8) proposes. We do not know. Nor do we think our evolutionary future is knowable beyond the realization that hominidae will speciate if we follow our urge to explore space. Despite the conceit evidenced in the species name we apply to ourselves, we are in no better position to forecast the exact course of our future evolution than were those first Australopithicines theirs. If they, five million years ago, could not have even dimly perceived the evolutionary consequences of their descent from the forest into the savanna, how could we, despite all our knowledge, know what evolutionary developments will flow from our journey to the stars?